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Thin film CZTS solar cells made by Pulsed Electron Deposition

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Copper Zinc Tin Sulfide (Cu_2ZnSnS_4 or CZTS) is a promising new material for thin film solar cells because it is made from cheap, abundant, non-toxic elements. It is similar to the solar cell material Copper Indium Gallium Diselenide (CIGS) which is already in commercial production. Unlike CIGS, CZTS does not have constituents that are rare in the Earth's crust and it is therefore suited for truly large-scale implementation. Adding to the allure, CIGS and CZTS are both well suited for building-integrated photovoltaics because they can be made on semi-flexible or curvy substrates and even directly on ceramic building elements.

Pulsed electron deposition (PED) is a relatively new low-cost, low-temperature vacuum-based method that has been used successfully to make CIGS > 18 % efficient (the CIGS world record is 21,7 %) [1, 2]. For CZTS, the world record efficiency is currently 9.4 % [3]. Usually both CIGS and CZTS need to be annealed at relatively high temperature (570 °C for CZTS) but with pulsed electron deposition enough energy is provided by the electron pulses to avoid high temperature annealing for CIGS. The question is whether this is also the case for CZTS. Therefore in cooperation with IMEM-CNR in Parma, Italy, we have carried out the first attempt to make CZTS by PED. We found that thin films deposited at 250-325 C (Fig. 1) have the correct CZTS crystallographic structure as measured by X-ray diffraction and have few secondary phases. However they are not fully dense and are low in S. The first trial solar cells with as-deposited films yielded a maximum efficiency of 0.2 %. This may be improved by controlling the film thickness and providing a heat treatment (preferably in situ, avoiding the use of an extra 570 °C annealing step in an oven), using a more uniform target of the correct composition and possibly doping with alkali metals.

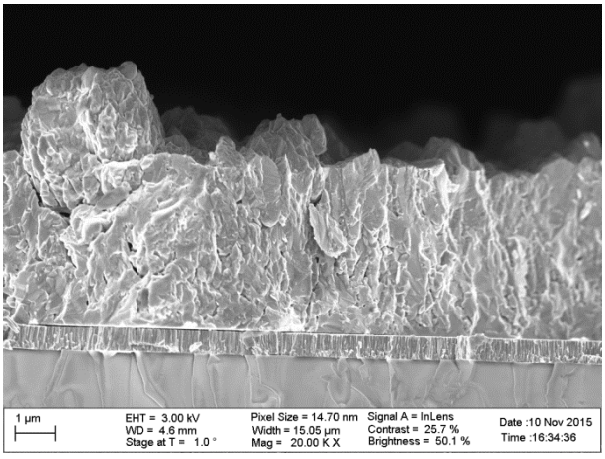

Fig. 1: SEM cross-sectional image of a CZTS layer identical to the one used in a 0.2 % efficient solar cell. The CZTS layer (4-5 µm thick) is deposited on a 500 nm layer of Mo that has been sputtered on soda lime glass.

[1] Rampino et al., J. Renew. Sustain. Energy **7**, 013112 (2015).
[2] Jackson et al., Phys. Status Solidii RRL **9**, No. 1, pp 28-31 (2015).
[3] Tajima et al., poster CP3-14 at the EMRS Spring Meeting in Lille, May 14, 2015.